

Drell-Yan Simulation in Run 16

fsPHENIX Workshop

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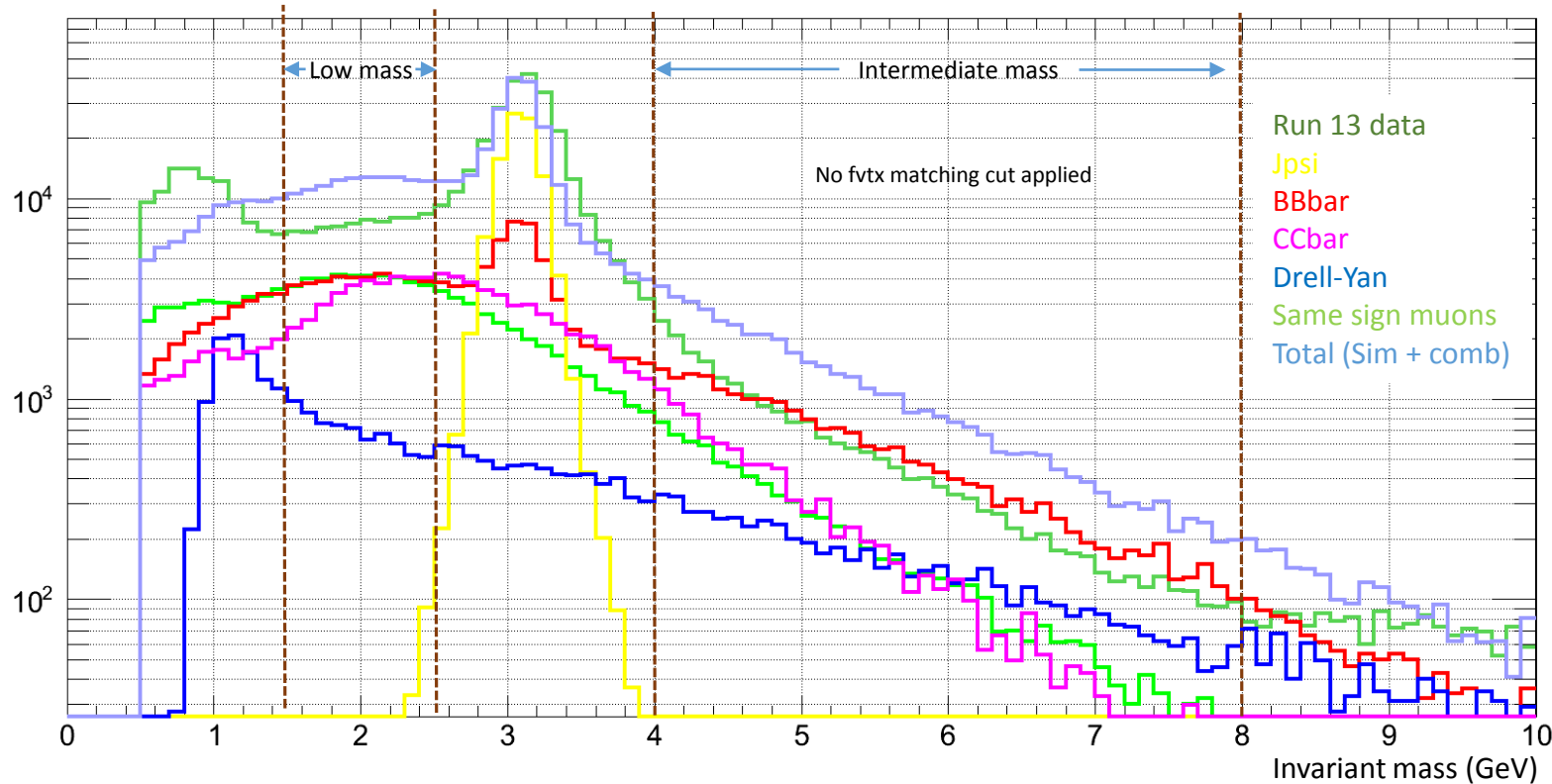
Introduction

- We are trying to study the possibility for Drell-Yan measurement in Run 16
 - It is closely related to Run 12, Run 13 and Run 15
- To make the 1st collider based polarized Drell-Yan measurements
- Current data
 - Run 12 510 GeV Longitudinally Polarized
 - Run 13 510 GeV Longitudinally Polarized
 - Run 15 200 GeV pp and pA – Transversely polarized
- With the current data we explore the possibility of Drell-Yan to dimuon measurements
 - Measure p_T and Mass dependent cross Section
 - A_{LL} in order to access sea quark polarization (But statistics is too low)
- FVTX is important for this measurement (15% of dimuon data)
- Future data
 - Run 16 510 GeV Transversely polarized PP
 - Goal is to measure A_N of Drell-Yan pair
 - Look for modified universality of the TMD pdfs and evolution

Main problem for the future Drell-Yan study

- Quantify statistics vs. the run time
 - possibility for Run 16 and very small possibility in Run 17
 - Studying the new DY Pythia configuration
 - With a realistic projection of VTX and FVTX acceptance
- Quantify the signal to background
 - We developed a set of tools to separate signal from background (2nd section of this talk)
 - Still using them to analyze the existing data
 - Goal is to quantify signal to background ratio
- A_N projection and physics impact
 - Need at least a few percent level statistical precision to have any physics significance
 - Both high and low mass Drell-Yan will be considered although statistics is hard for high mass
 - Can we do that before beam use proposal?

Invariant mass spectrum for Run13 and simple simulation



The yields are normalized to the integrated luminosity of real data of 30 cm vertex

Simulations are done with PYTHIA6 -> PISA

Simulations agree with the data to a factor of few

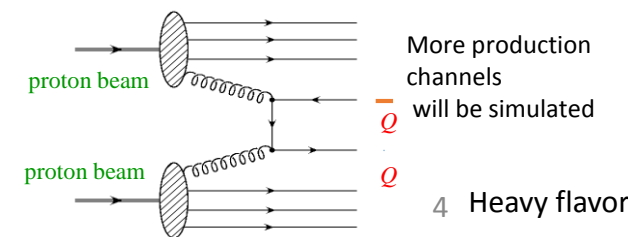
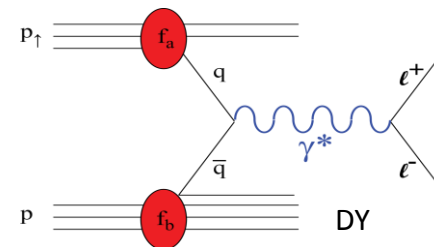
Caveat :

- Need to update DY pdf and K factor
- Currently heavy flavor $g + g \rightarrow Q + \bar{Q}$ only
- No trigger efficiencies are included

Next step :

- Plan to use fsPhenix Pythia event pool
- Improve Simulation

- High mass (4 – 8 GeV) Drell – Yan is a small fraction of the data



Validation of the Heavy Flavor simulation

- Heavy flavor simulation should be validated
 - we have Run 12 and Run 13 510GeV data
- PHENIX has multiple measurements for charm and bottom production which are in agreement with pQCD values.
- BBar cross section is measured by looking at the high mass same sign dimuons

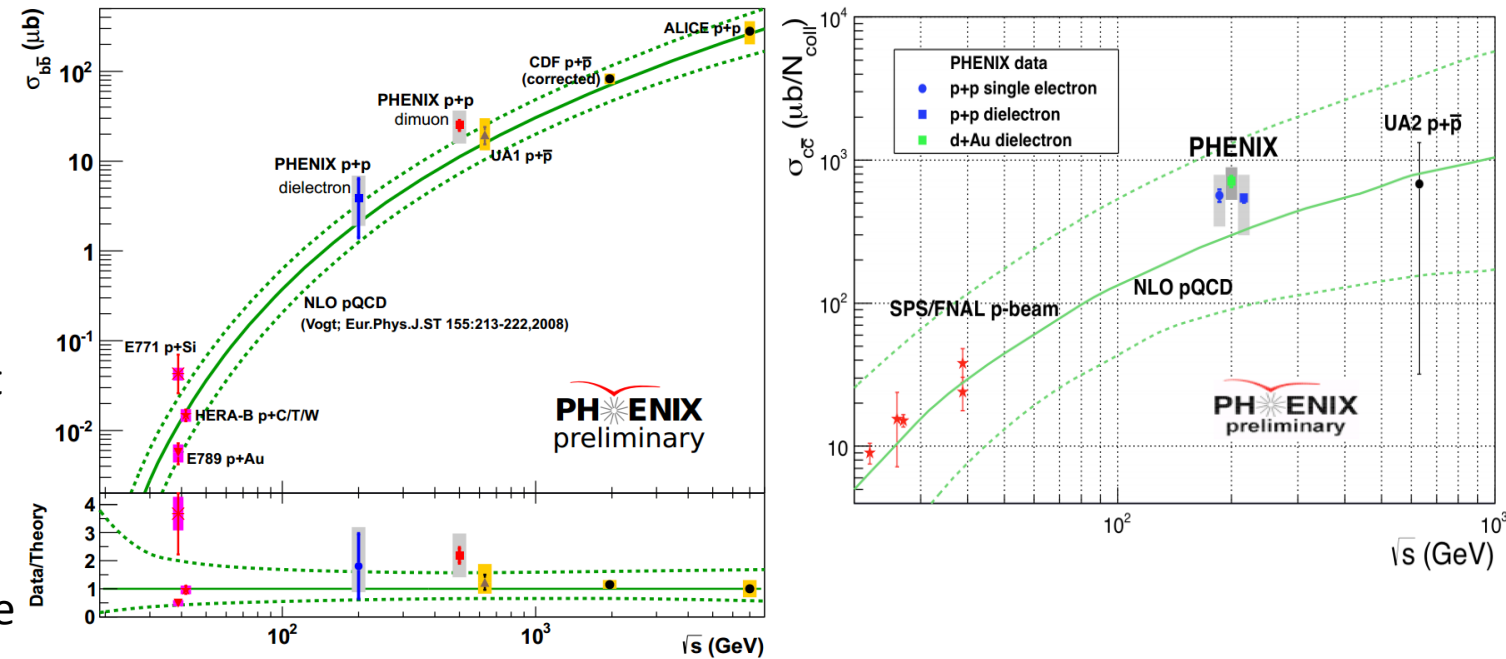
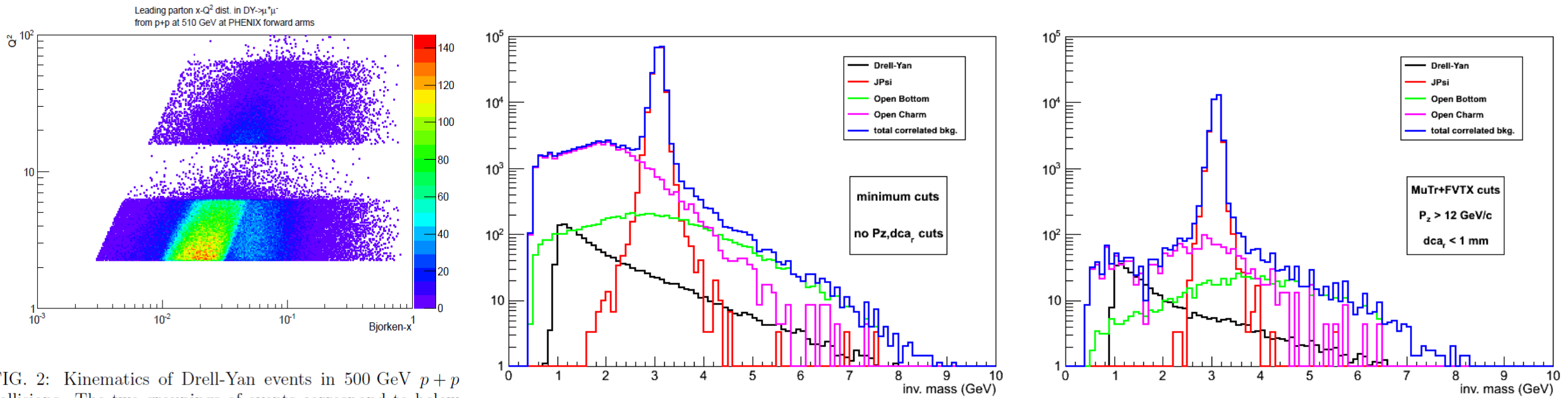


Figure 6.17: Comparison of $\sigma_{b\bar{b}}$ at different center of mass energies with NLO pQCD theory. The data point labeled “dimuon” is from this analysis. The bottom panel shows the ratio of data to NLO theory.

Pythia simulation done by Douglas E. Fields

Reference to Doug and Amaresh FVTX meeting talk 30th April 2014

- We are preparing to run a pisa simulation expected Run 16 acceptance including fvtx and vtx.
- Early result without using Silicon detector shows P_z and rough fvtx cut is very useful in suppressing the background in low mass region



Estimation of statistics

Estimation of statistics

Reference to Doug and Amaresh FVTX meeting talk 30th April 2014

	200 GeV	510 GeV
$\sigma_{LowM_{inv}}^{DY}$	$2 \times 2052 \text{ pb}$	$2 \times 2457 \text{ pb}$
$\mathcal{L}_{Delivered}/week$	(14) 21 pb^{-1}	(40) 176 pb^{-1}
$\mathcal{L}_{Delivered}(20 \text{ weeks})$	(280) 420 pb^{-1}	(800) 3520 pb^{-1}
P	(0.59) 0.70	(0.56) 0.70
$Lifetime$	(0.50) 0.70	(0.50) 0.70
$\epsilon_{\pm 10cm}$	(0.30) 0.40	(0.30) 0.40
$\mathcal{L}_{Recorded}$	(42) 118 pb^{-1}	(120) 896 pb^{-1}
$N_{Produced}^{DY}$	(172K) 484K	(590K) 4,845K
ϵ_{Acc}	0.52	0.51
N_{InAcc}^{DY}	(90K) 252K	(301K) 2,471K
ϵ_{Rec}	0.058	0.11
N_{Rec}^{DY}	(5.2K) 14.6K	(33K) 272K
ϵ_{Cuts}	0.43	0.45
$N_{AfterCuts}^{DY}$	(2.2K) 6.3K	(15K) 122K
r	0.5	0.5
$\delta\sigma_{LowM_{inv}}^{DY}$	(2.1%*) 1.3%*	(0.8%*) 0.3%*
$\delta A_N^{DY, LowM_{inv}}$	(10.1%*) 5.1%*	(4.1%*) 1.1%*

*Statistical only.

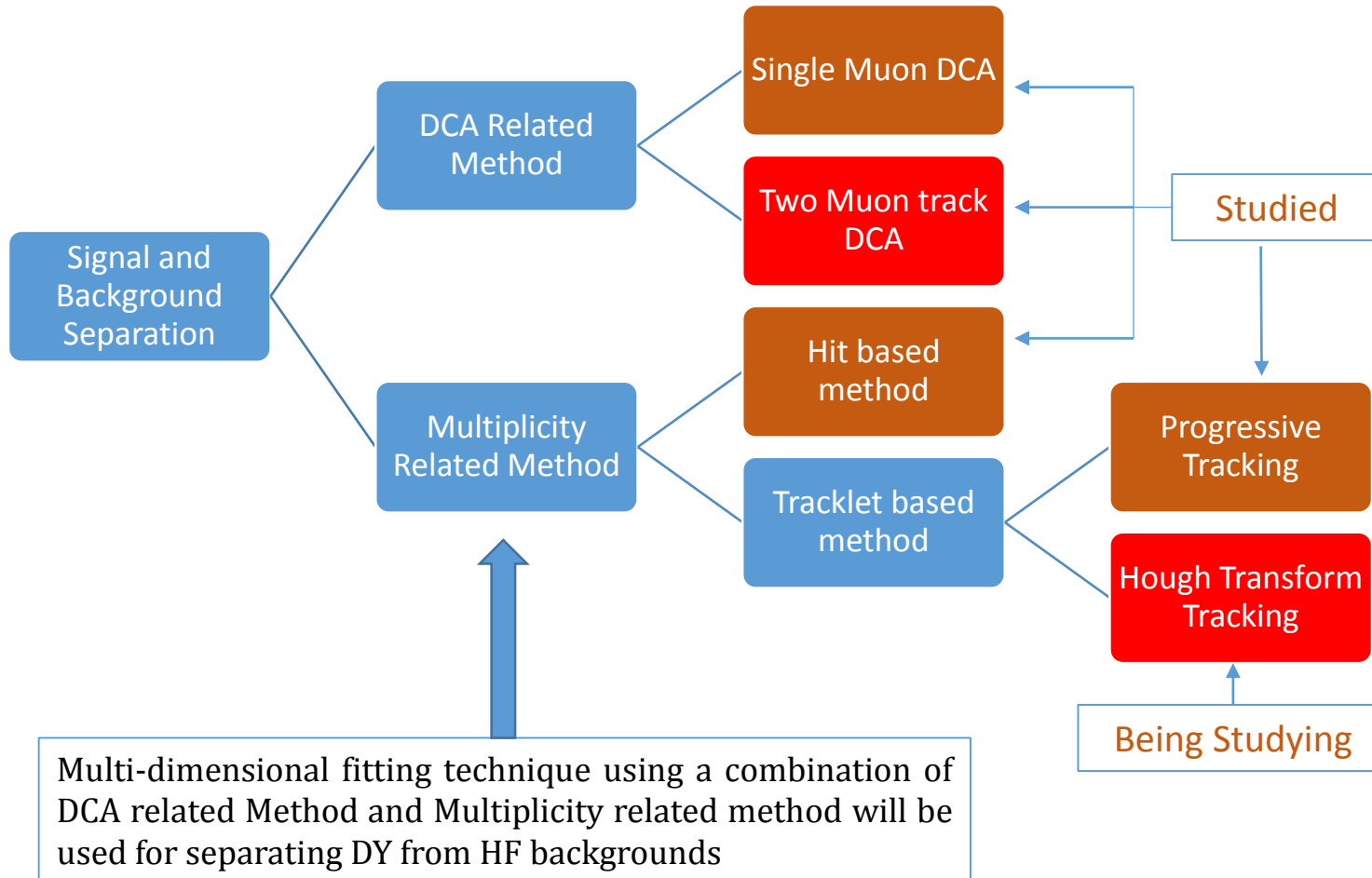
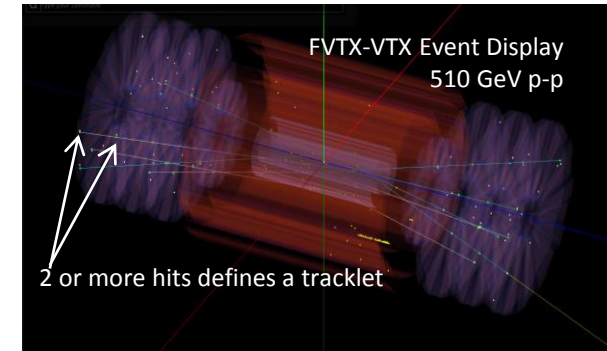
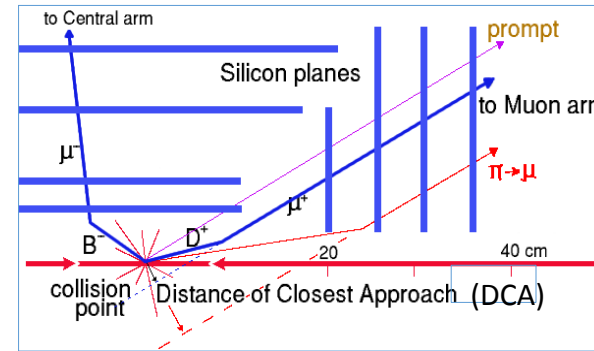
No realistic application of acceptance of vtx and fvtx

Some equations used	$\delta A_N = \frac{1}{P} \frac{1}{\sqrt{\frac{1}{2}N}}$	$\delta A_N^{Phys} = \frac{\sqrt{(\delta A_N^{incl})^2 + r^2 \cdot (\delta A_N^{BG})^2}}{1-r}$
$r = N^{bg} / N^{incl}$	$A_N^{Phys} = \frac{A_N^{incl} - r \cdot A_N^{BG}}{1-r}$	$\delta A_N^{sig} \sim \frac{\delta A_N^{incl}}{1-r} = \frac{1}{P} \frac{1}{(1-r)\sqrt{\frac{1}{2}N}}$

- CTEQ6 PDFs were used for the cross section predictions
 - GEANT studies and simulations were used to estimate the efficiencies.
 - The uncertainty of background asymmetry is assumed to be zero in the δA_N Calculation
 - My simple simulation comparison with real data show that we can obtain about 300 DY events at a signal to Background ratio of 1:1 for run 13, 150 pb^{-1} 30cm vertex after the fvtx cuts. This would lead to $\delta A_N \approx 6\%$ at a 896 pb^{-1} luminosity.
- Reference to my Spin PWG talk 11th February 2015
- I have started the new simulation following the fsPHENIX Pythia production
 - Plan is to get four categories of statistics
 - Simulation without FVTX matching required
 - Simulation with both tracks having FVTX matching
 - Simulation with VTX vertex and both tracks having FVTX matching
 - Simulation with VTX vertex and single track having FVTX matching

Analysis of existing data

Analysis Strategy



Single Muon DCA :

- High precision in separating the secondary vertex
- But require VTX precision

Two Muon track DCA :

- Do not require VTX

Hit based method :

- Simple method, Vulnerable to backgrounds

Progressive Tracking :

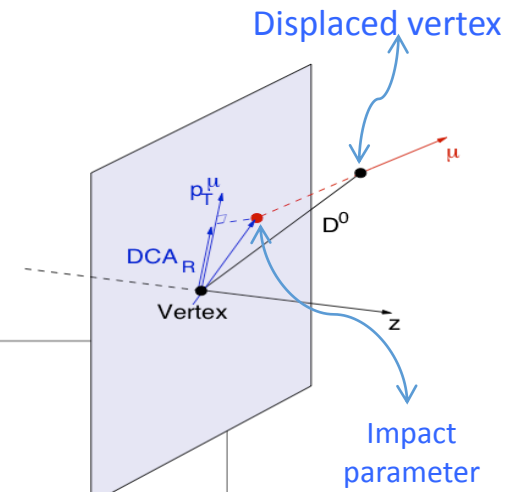
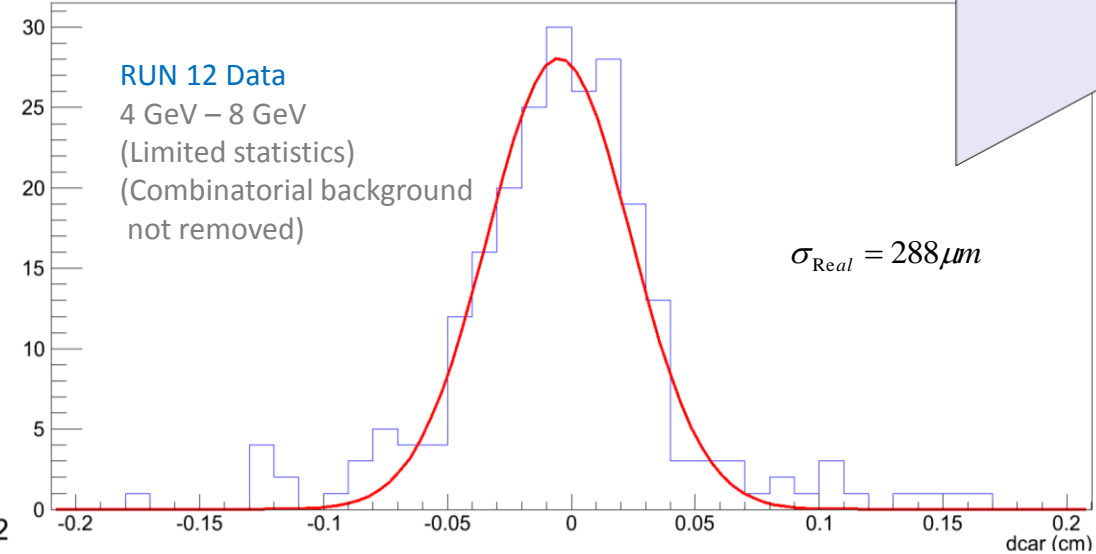
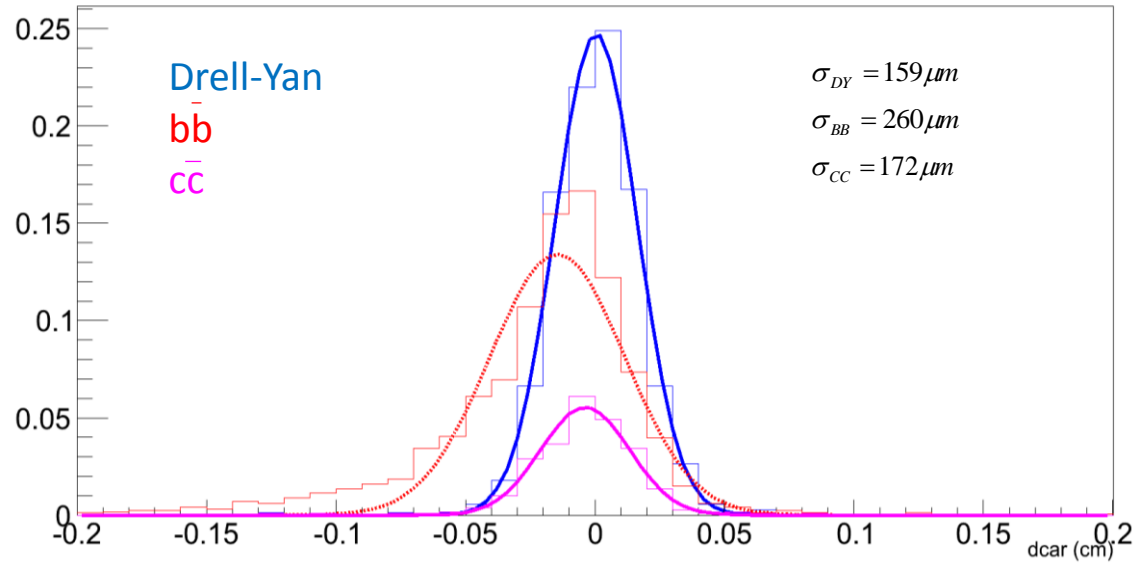
- Available early in production

Hough Transform Tracking :

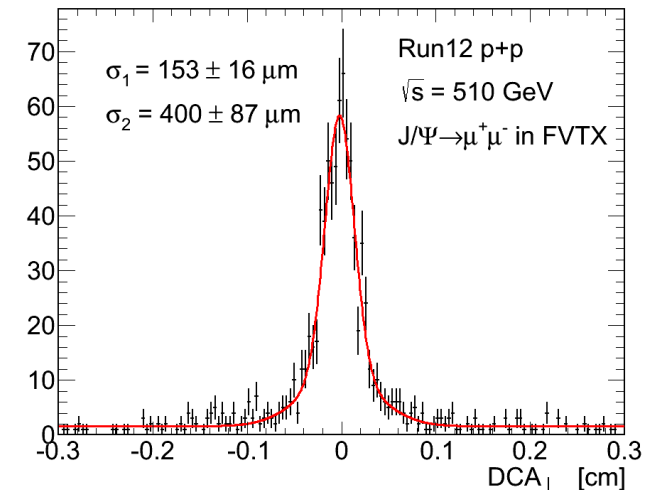
- Perfected later and more robust tracking

Single Muon DCA

Reference to my Spin PWG talk 13th August 2014



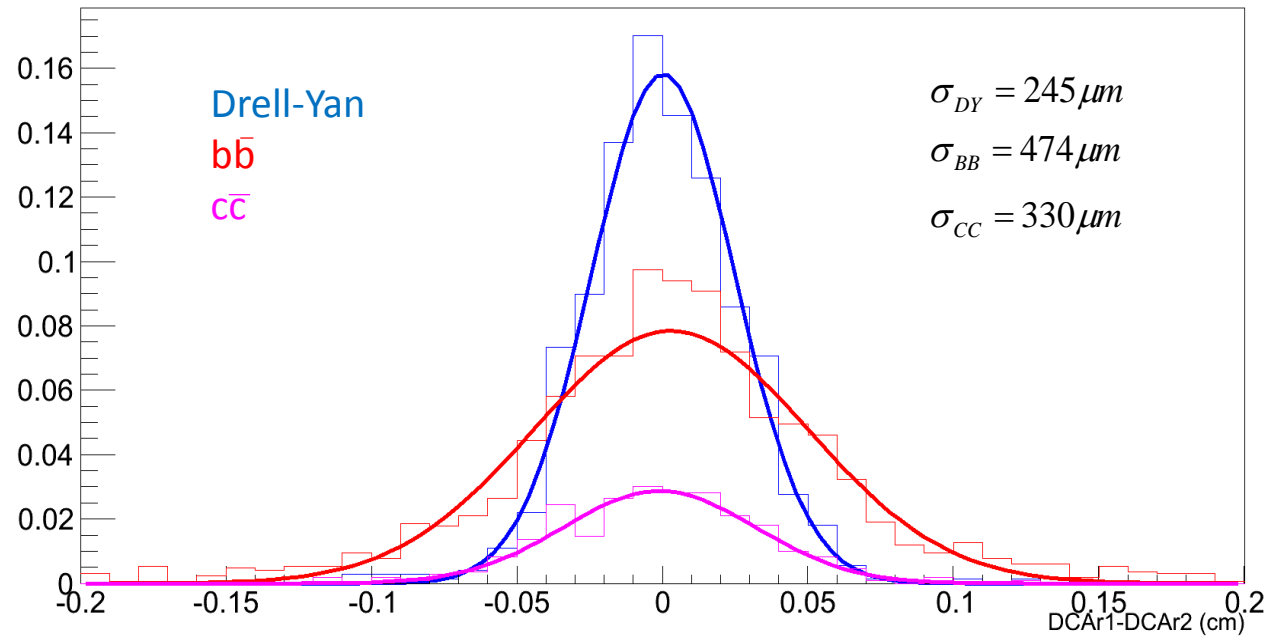
- Limited statistics is a major challenge in the Drell-Yan analysis
- Average beam position is very effective in bring up DCA precision in Run12 production
- Will be used as one of the two components of the 2-D fitting



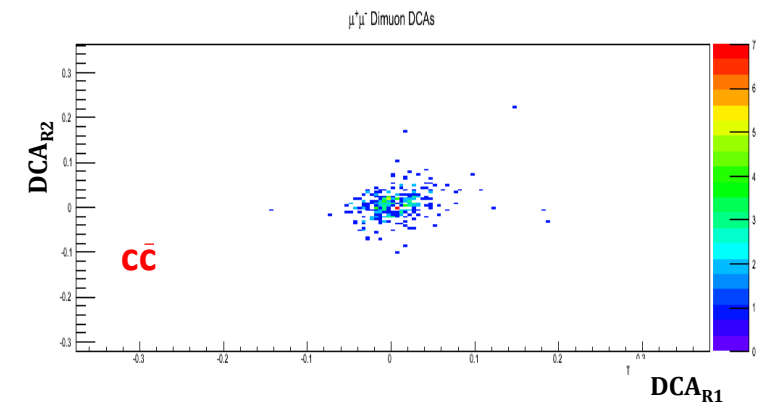
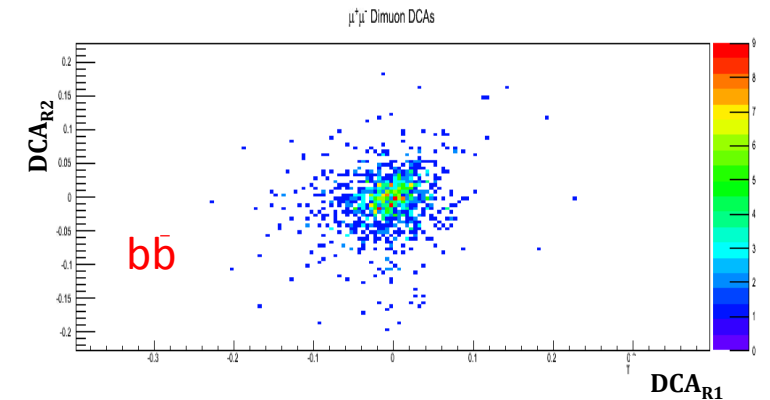
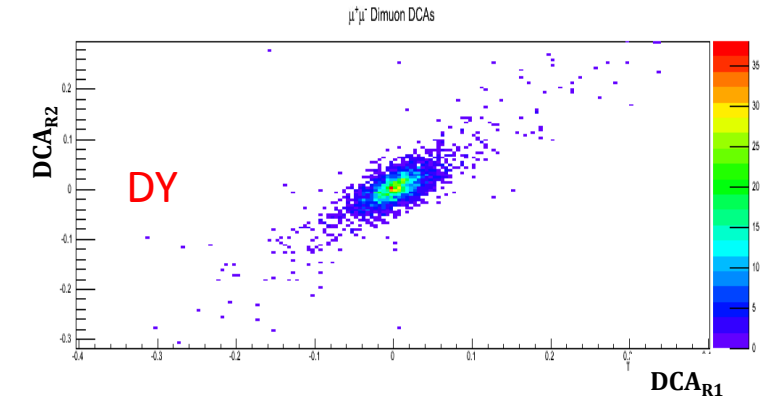
Di Muon tracks DCA

Reference to Jins talk on 23 April 2014 in FVTX meeting

- 2D correlation between two tracks shows the vertex z contribution
- Vertex z contribution cancelled in $DCA_{R1} - DCA_{R2}$
- DCA_R difference between two tracks bring back the differentiating power between heavy flavors and Drell-Yan process



VTX not used in this analysis



Summary for dca and introducing the multiplicity method

- DCA provide a robust tagging for heavy flavor.

- Use single track DCA_R :

This method gives the best information, but will require precise vertex reconstruction.

- We can use this method for Run12
- After calibrating the VTX we can use this method for Run 13

- Two muon tracks + average beam matching method :

For vertex range outside VTX or vertex that VTX failed to reconstruct, we can use this method

- Simulations done for Run 13

- But DCA does not have a very high rejection power

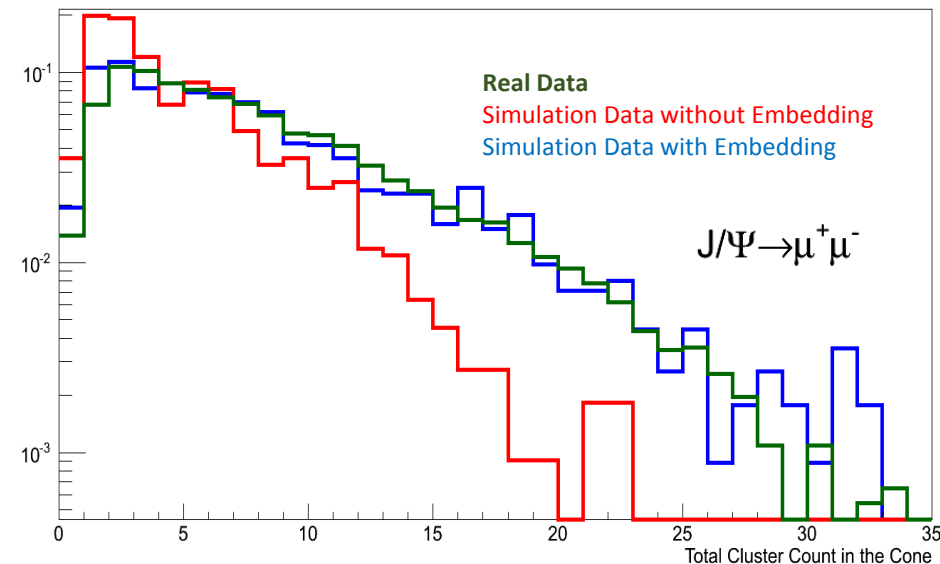
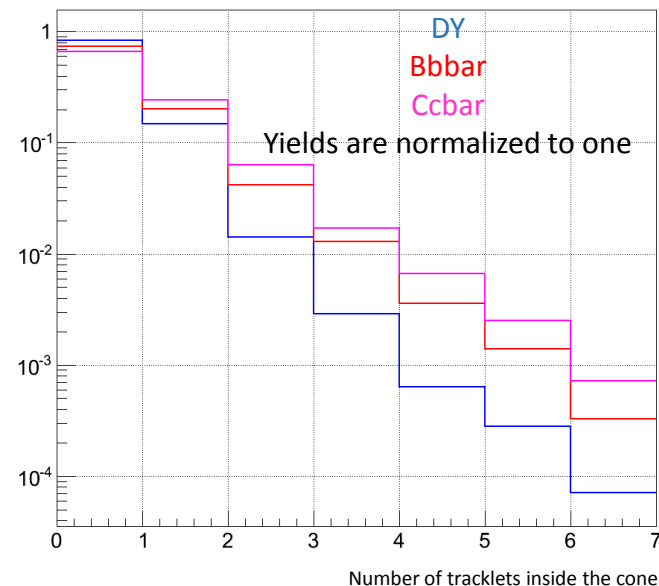
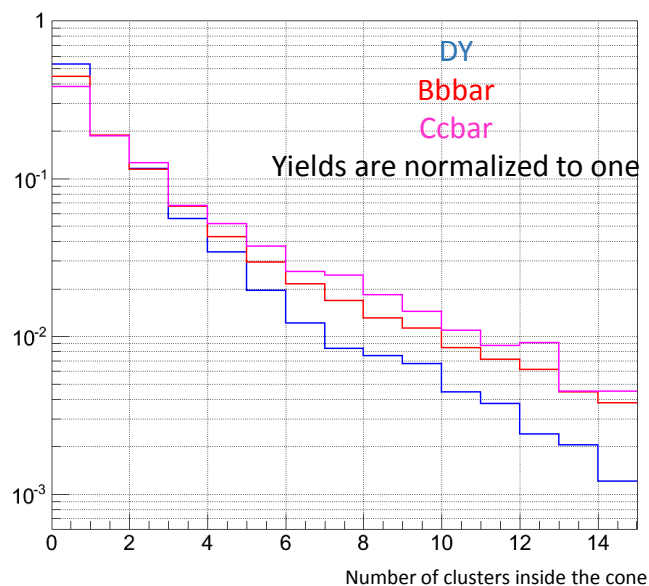
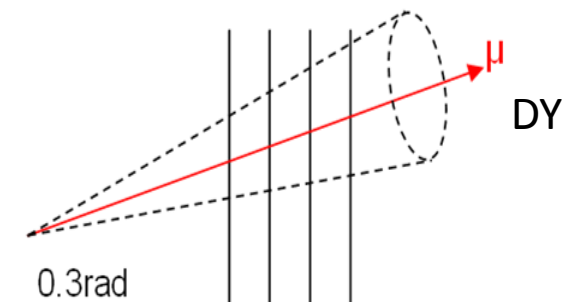
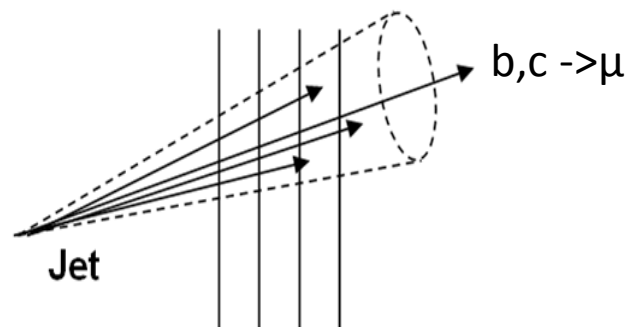
- Meanwhile we found that multiplicity counting has good rejection power

- Three methods of multiplicity will be discussed in the next slides

- Multidimensional fitting technique using a combination of DCA related Method and Multiplicity related method will be used for separating DY from HF backgrounds

Hit based method

Reference to my Spin PWG talk 11th February 2015

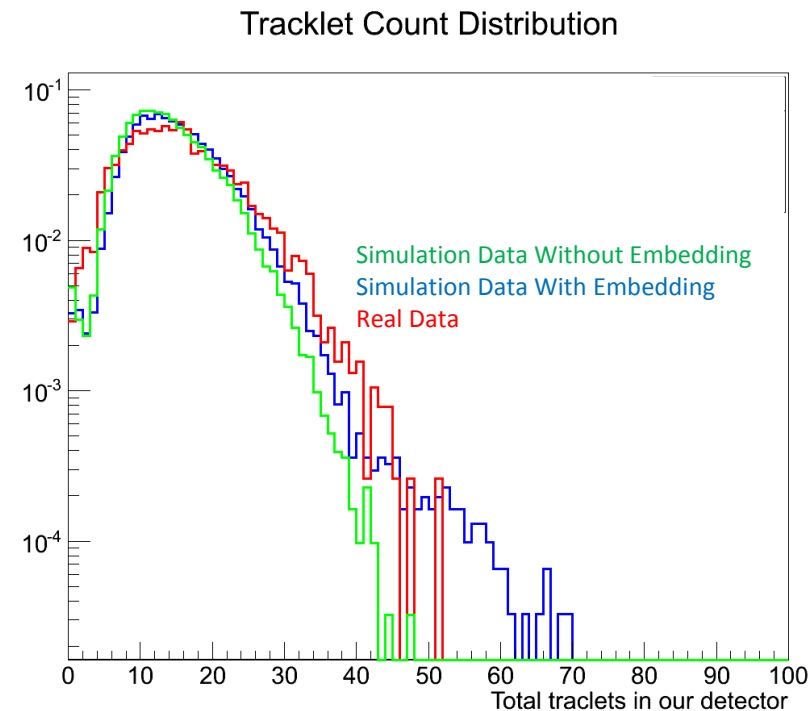
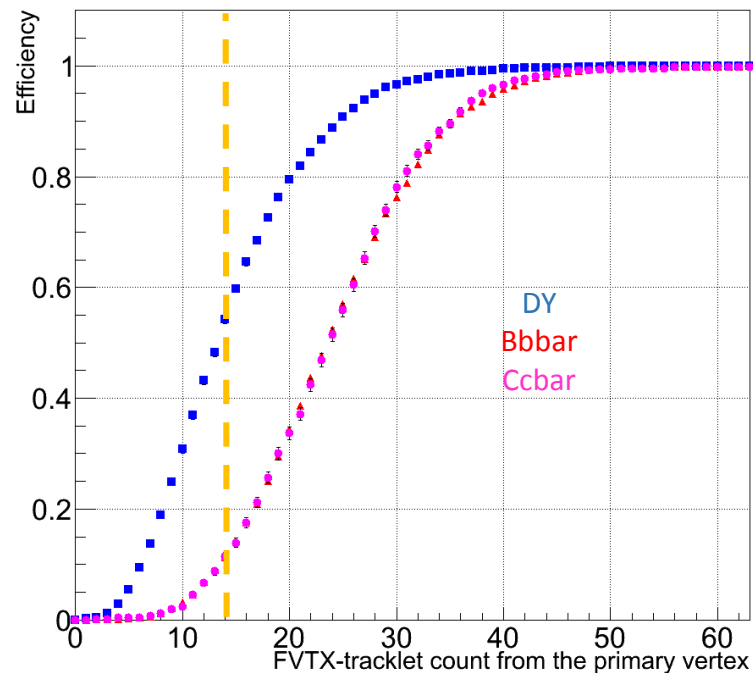
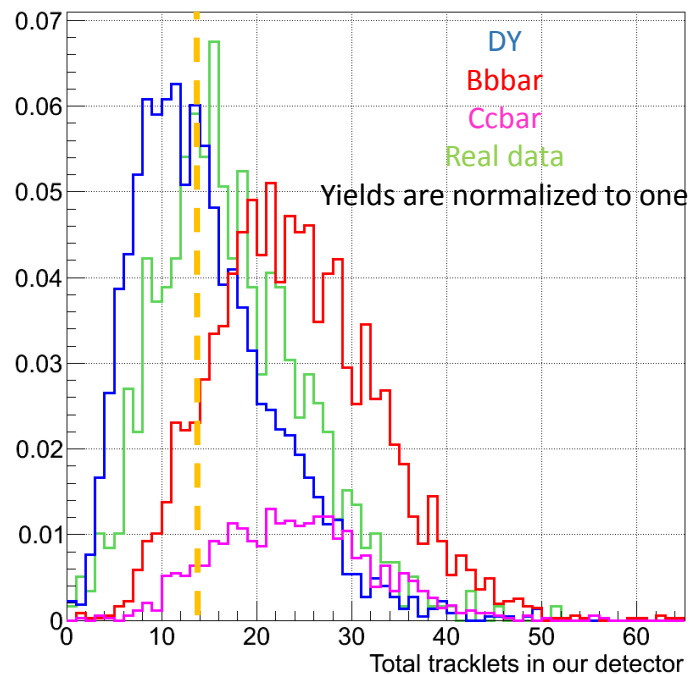


- Basics
 - Draw a cone around the primary muon track
 - Count the number of clusters inside the cone
- This method was not much effective in Drell – Yan study
- But we can see that our cluster simulation match with real J/Psi data which is very hard to do

Show where we presented

Tracklet based method with Progressive Tracking

Reference to my Spin PWG talk 11th February 2015



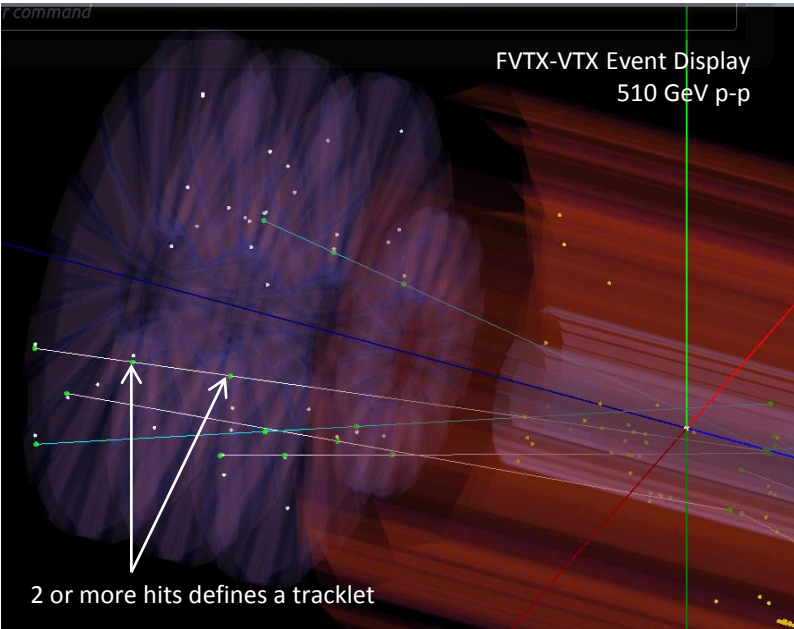
- The 1st plot shows the Tracklet distribution for dy,bb,cc and real data
- Second plot shows the cumulative probability (efficiency) distribution for the simulation processes
- Third plot shows the tracklet distribution for the J/Psi (to test the consistency of our simulation with real data)

Hough Transform Tracking

- Hough Transform is available now for tracking
 - Developed by Aaron Key
 - Better quality tracking
 - More reliable
 - Better tracking for run 13 (no vtx)

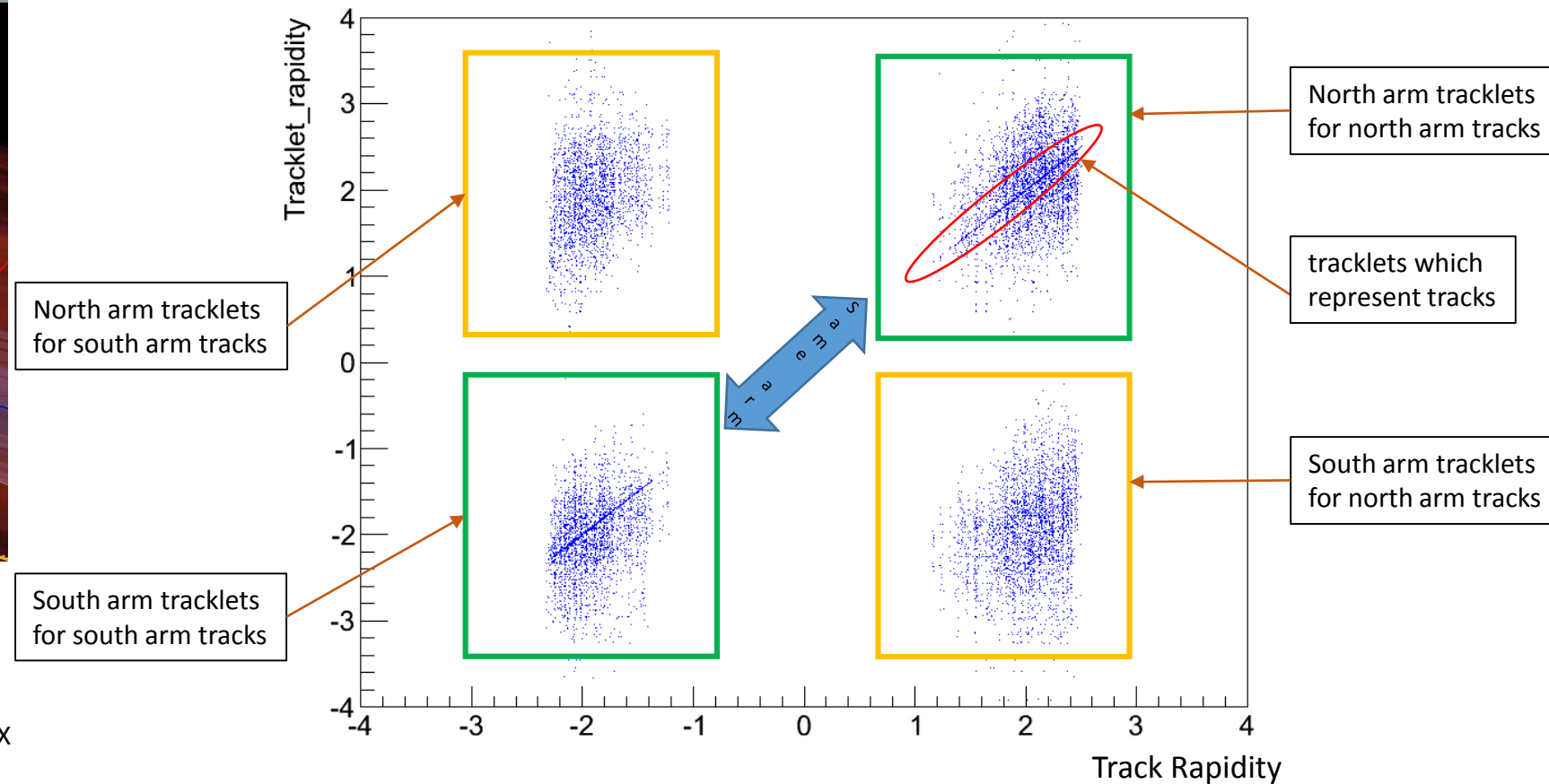
Defining the Tracklets in FVTX and Tracklet distribution

Reference to my Spin PWG talk 11th February 2015



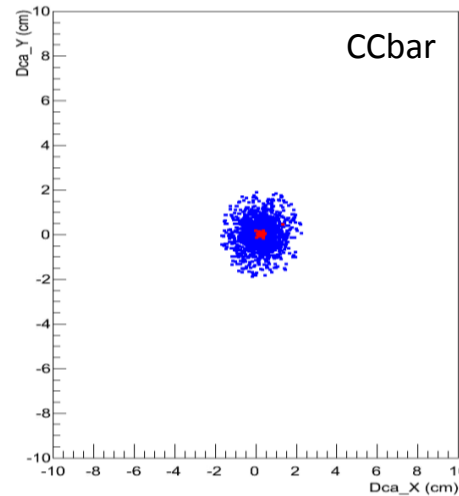
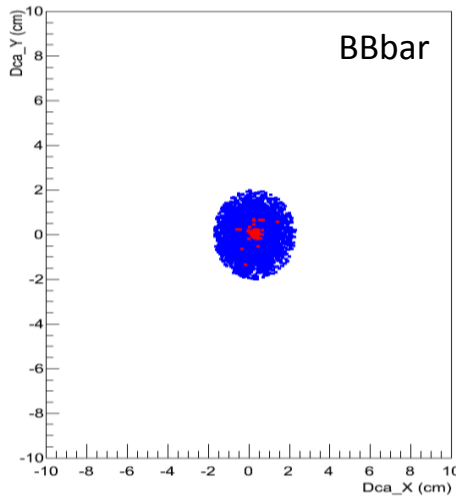
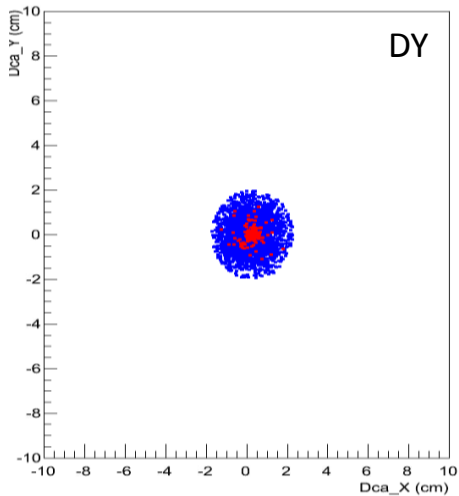
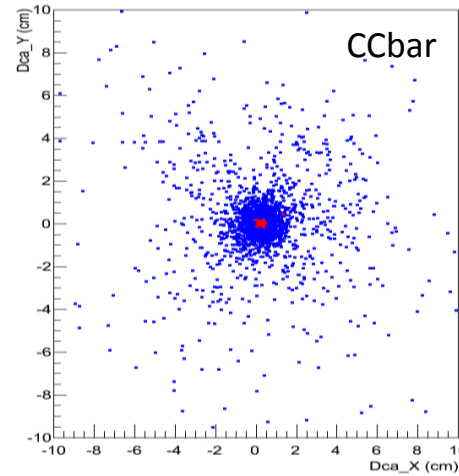
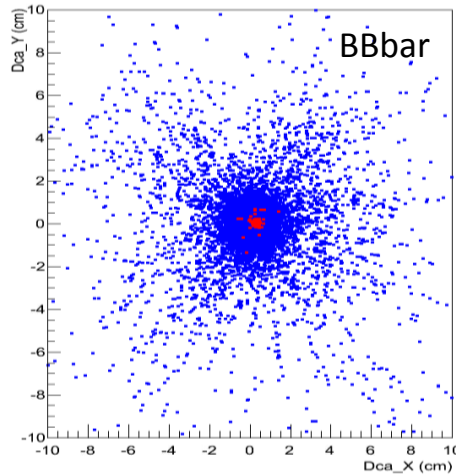
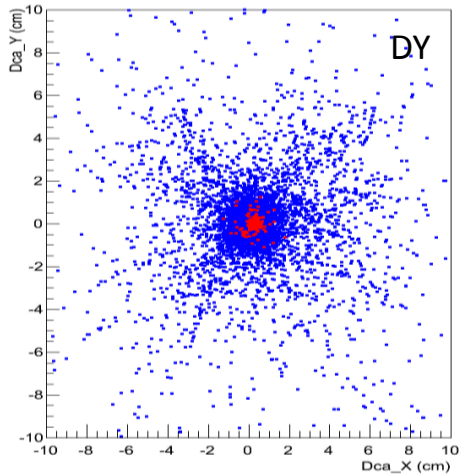
Tracklets projected to xy plane at Z = Event Vertex Plane

Tracklets require at least two hits in two stations of the FVTX



DCA_X and DCA_Y for the Tracklets with embedding

Reference to my Spin PWG talk 11th February 2015



Defining a cut for the dca X and dca Y

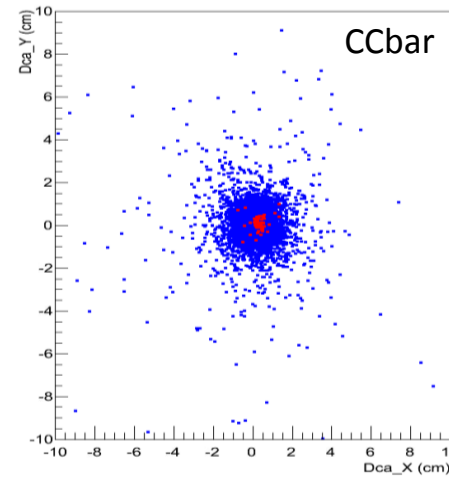
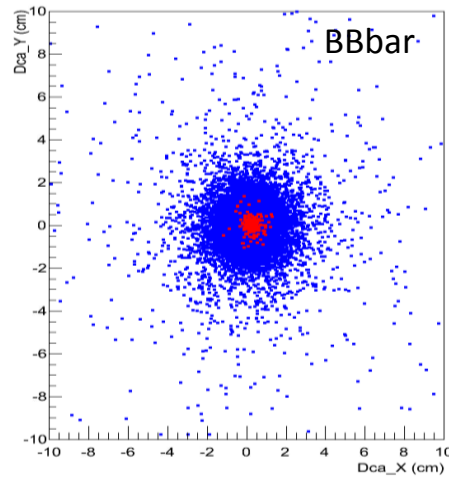
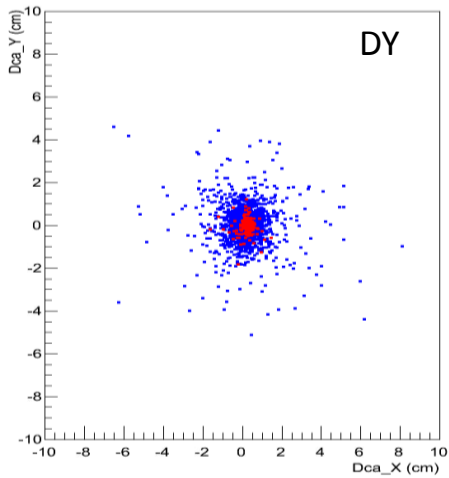
$$R = \sqrt{(DCA_X - Evt_Vtx_X)^2 + (DCA_Y - Evt_Vtx_Y)^2}$$

Applying a cut at $R < 2.0$ cm

R cut will be applied in order to reject most of the background tracklets

eg : get rid of beam backgrounds

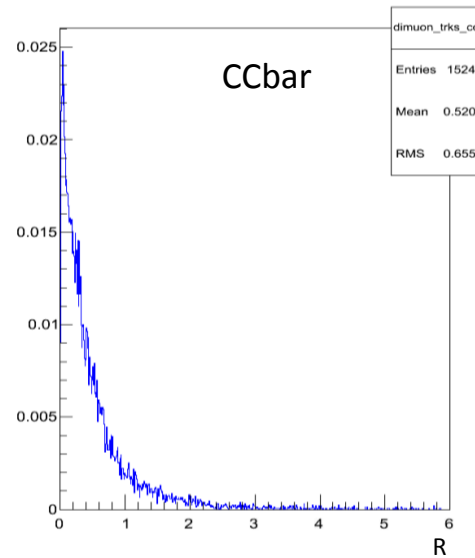
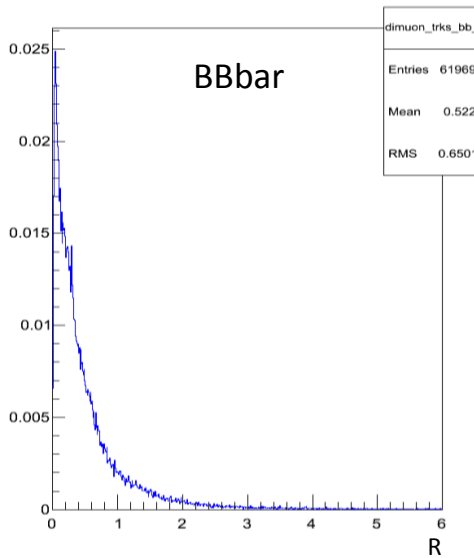
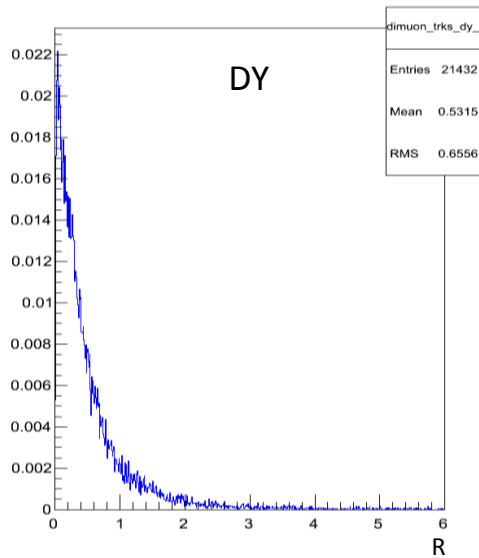
DCA_X and DCA_Y for the Tracklets without embedding



Defining a cut for the dca X and dca Y

$$R = \sqrt{((DCA_X - Evt_Vtx_X)^2 + (DCA_Y - Evt_Vtx_Y)^2)}$$

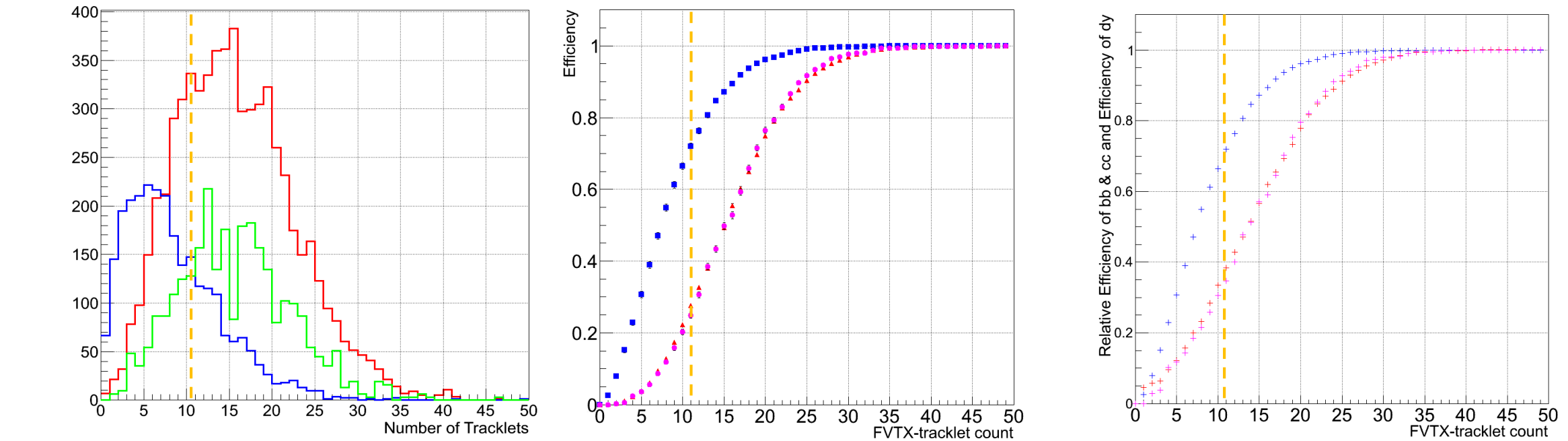
R distribution for different processors



R cut will be applied in order to reject most of the background tracklets from beam backgrounds

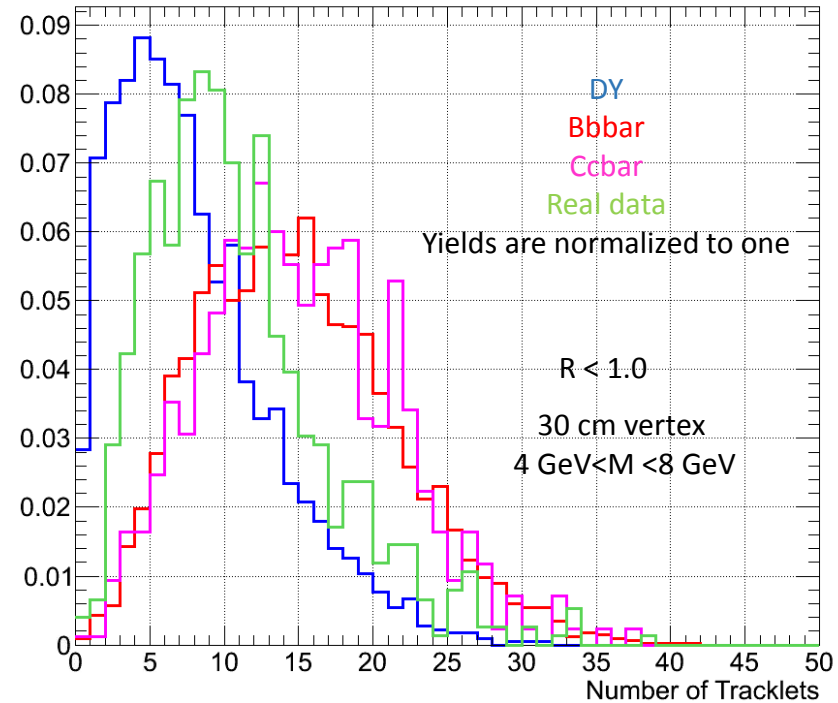
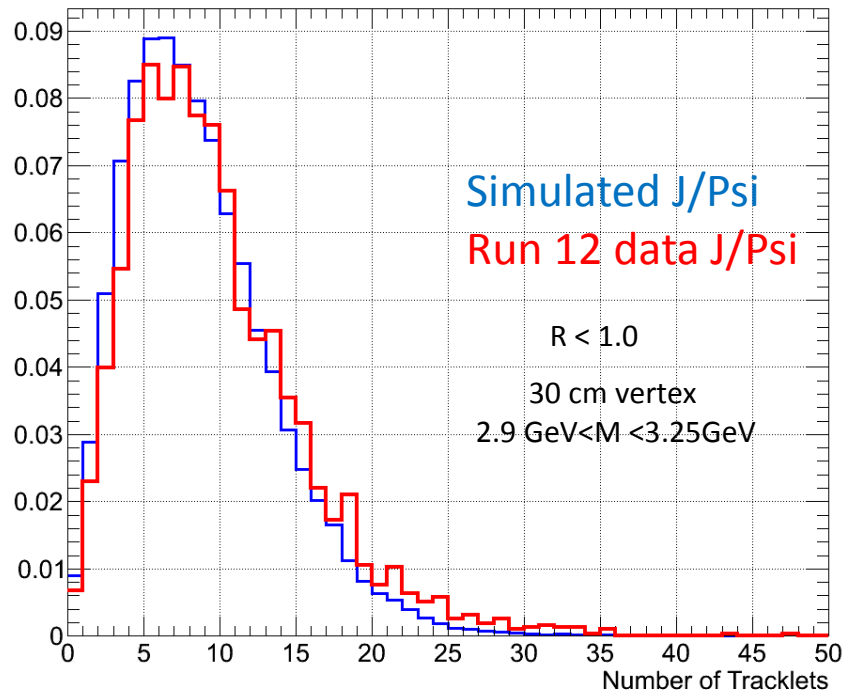
Total tracklets in FVTX

Reference to my Spin PWG talk 11th February 2015



R Cut	Cut at Tracklet Count	Drell-Yan efficiency	Drell-Yan efficiency/BBbar efficiency	Drell-Yan efficiency/CCbar efficiency	Cut at Tracklet Count	Drell-Yan efficiency	Drell-Yan efficiency/BBbar efficiency	Drell-Yan efficiency/CCbar efficiency
R < 3.0	12	65	3	3.2	14	74	2.4	2.4
R < 2.0	11	64	3.2	3.3	13	73	2.5	2.6
R < 1.0	9	61	3.5	3.8	11	72	2.6	2.8
R < 0.5	7	62	3.1	3.7	9	74	2.3	2.3

Checking the consistency with real data



- Plotting the Run 12 data for the J/Psi indicate that our tracklet simulation is much realistic
- Clock Filtered data embedding was done in order to account for the beam backgrounds

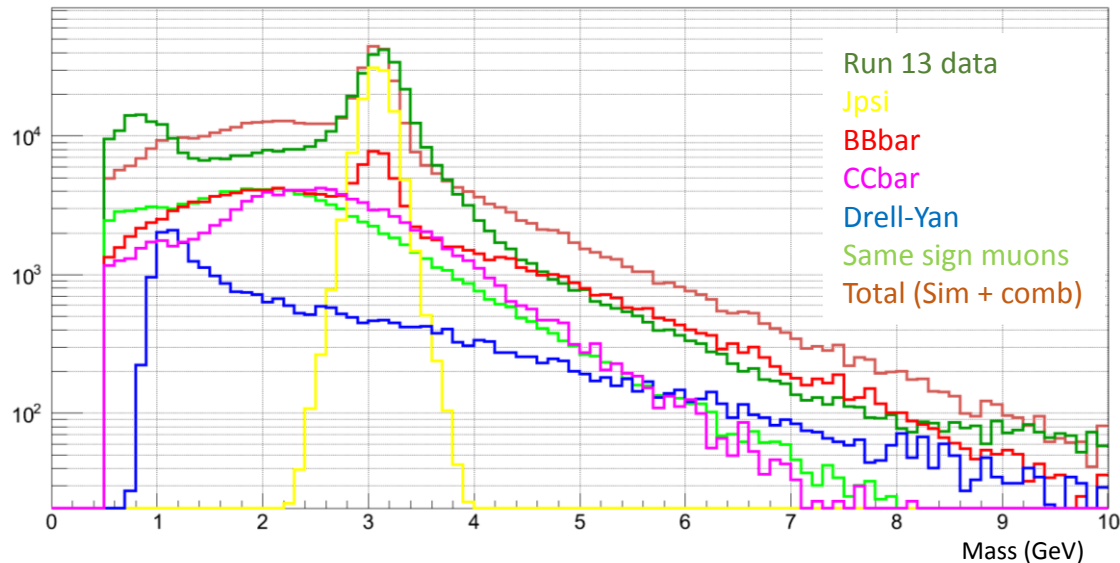
Plans

- Revise the simulation with new standard configuration
 - Both DY and HF background (can be done in 2-weeks)
 - Use real data to estimate hadron background
- Validation of simulation with real data (may need about 2-3 months)
 - Run 12 we have vtx with limited statistics and fvtx (50-70%)
 - Run 13 full statistics and fvtx but no vtx
 - b quark production cross-section
 - Estimate the Signal to Background ratio
- Preparation for beam use proposal
 - Revising the simulation and data validation can be done before the proposal
 - Developing the multidimensional fitting to estimate the signal to background ratio may not be developed before the proposal

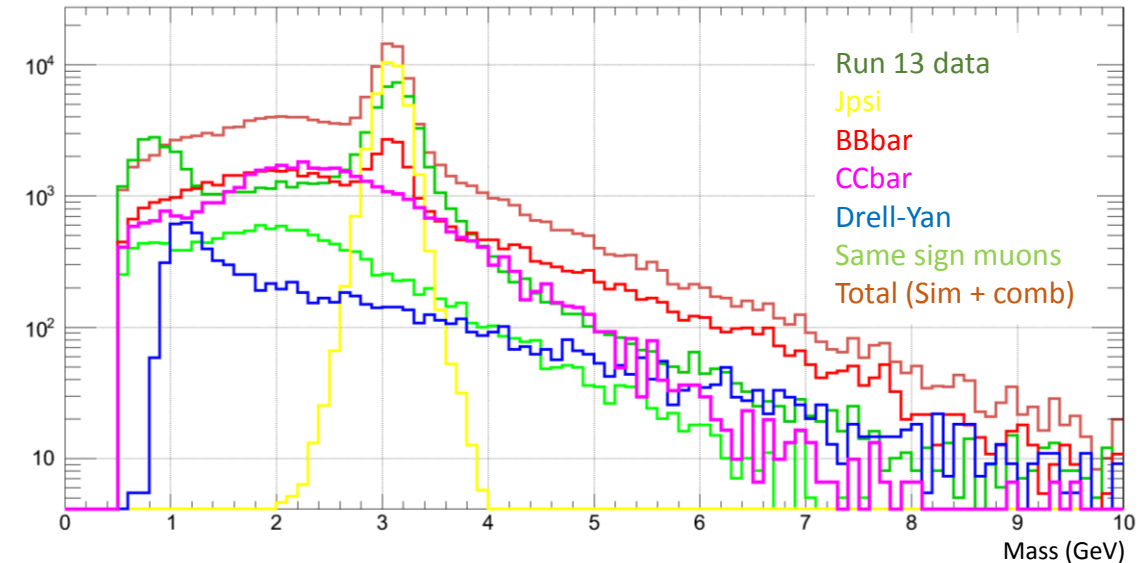
Back up slides

Mass Before and after FVTX matching

Before and after FVTX matching



Before and after FVTX matching



Preliminary simulation Summary

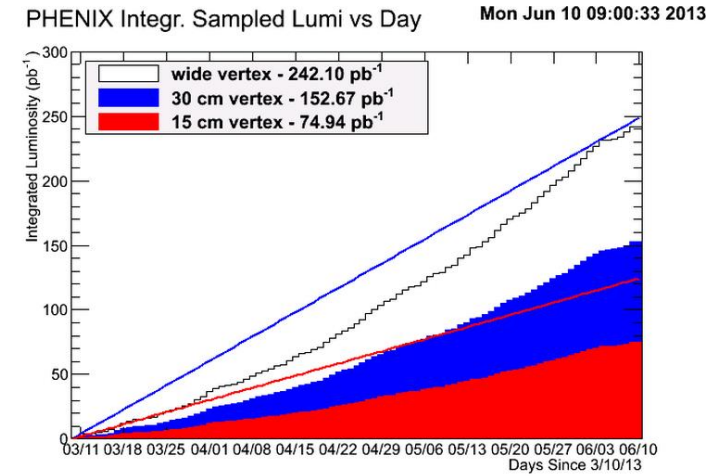
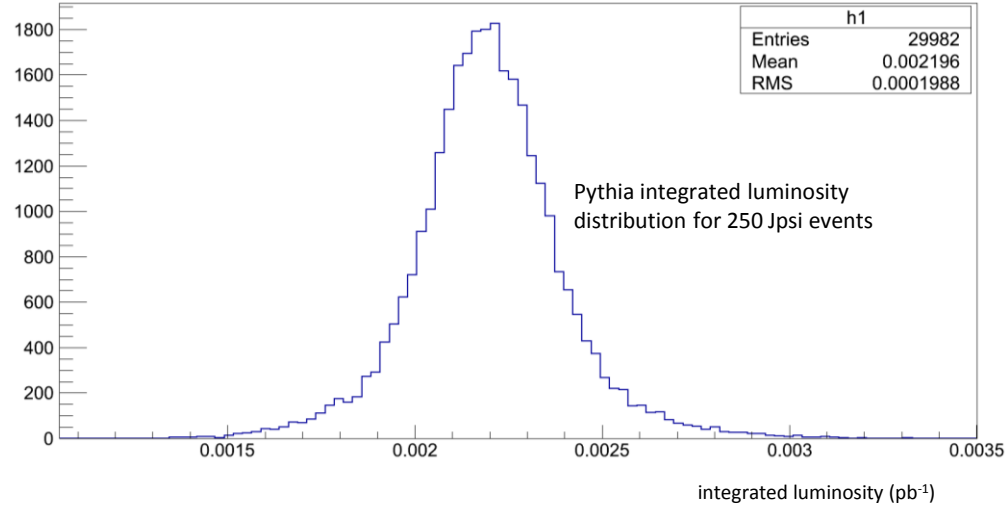
For - event vertex <30 cm
- 150pb-1 lumi

Process	After muon Cuts	After vertex Cut	After FVTX cuts	Tracklet Cut	dcar cut
DY	8442	8315	2685	2218	1958
BB	21652	21431	6321	2424	1417
CC	8883	8784	2765	1056	758
Real Data	38338	20856	3066 (15% of data)	1484	1077
combinatorial	13648	7304	1057	512	371

Signal : Background $\sim 1 : 1.1$

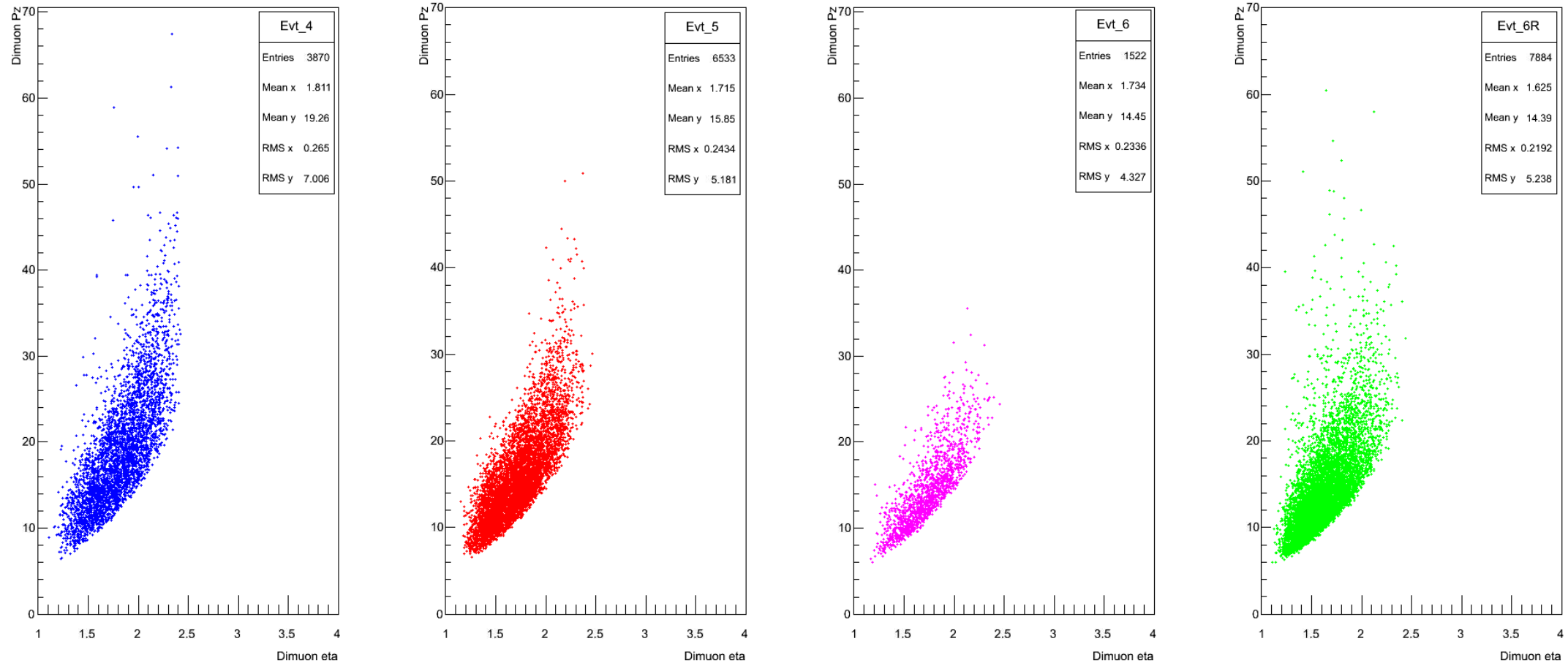
Expected number of Drell – Yan events for run 13 after all cuts ~ 300

Scaling to the integrated luminosity

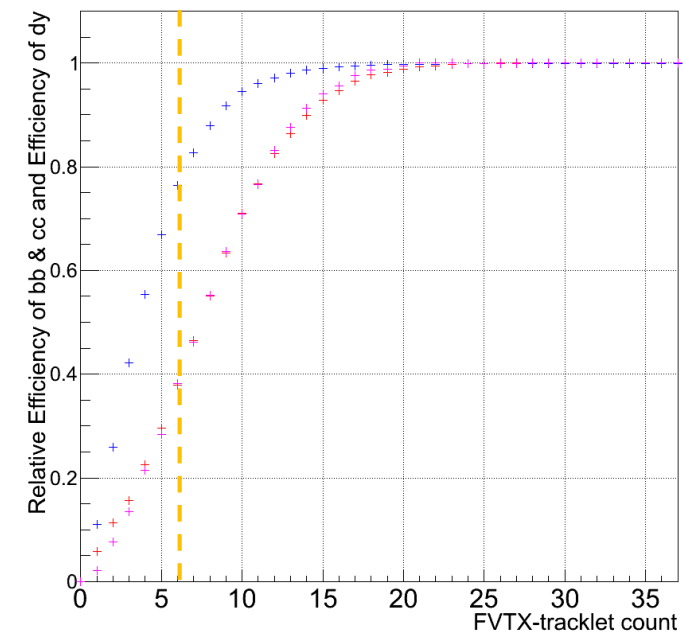
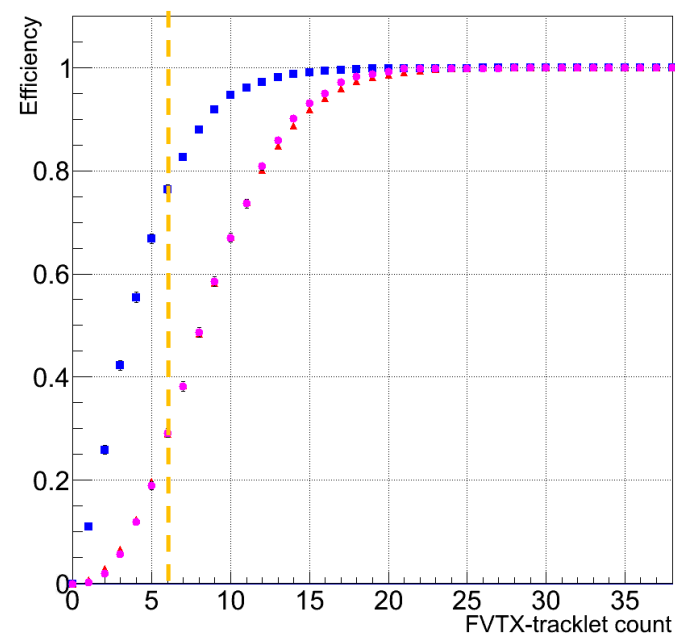
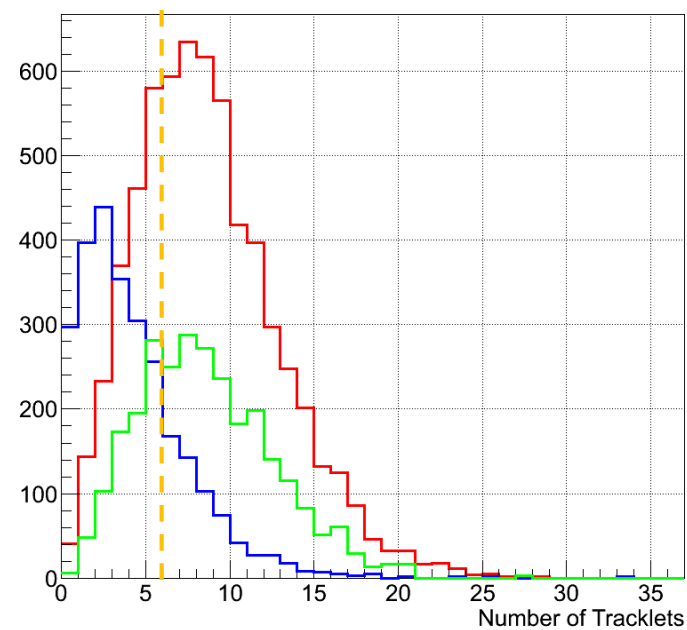


Process	Integrated Luminosity in generating 250 events	Events to generate to obtain 150pb-1 (Run 13, 30 cm vertex)	Scaling factor
Dy	0.0124	3029862	1.0000
bb	0.0084	4471920	1.4759
cc	0.0047	8019126	2.6467
Jpsi	0.0370	1013102	0.3343

Pz Distributions for intermediate mass Drell-Yan North Arm



Same arm tracklets



R Cut	Cut at Tracklet Count	Drell-Yan efficiency	Drell-Yan efficiency/BBbar efficiency	Drell-Yan efficiency/CCbar efficiency	Cut at Tracklet Count	Drell-Yan efficiency	Drell-Yan efficiency/BBbar efficiency	Drell-Yan efficiency/CCbar efficiency
R < 3.0	6	67	3.3	3.3	7	74	2.6	2.7
R < 2.0	6	70	3.1	3.3	7	78	2.5	2.7
R < 1.0	5	67	3.4	3.5	6	76	2.6	2.6
R < 0.5	4	68	3	3.4	5	78	2.3	2.4

Simulation Cross-Sections were with-in NLO theory

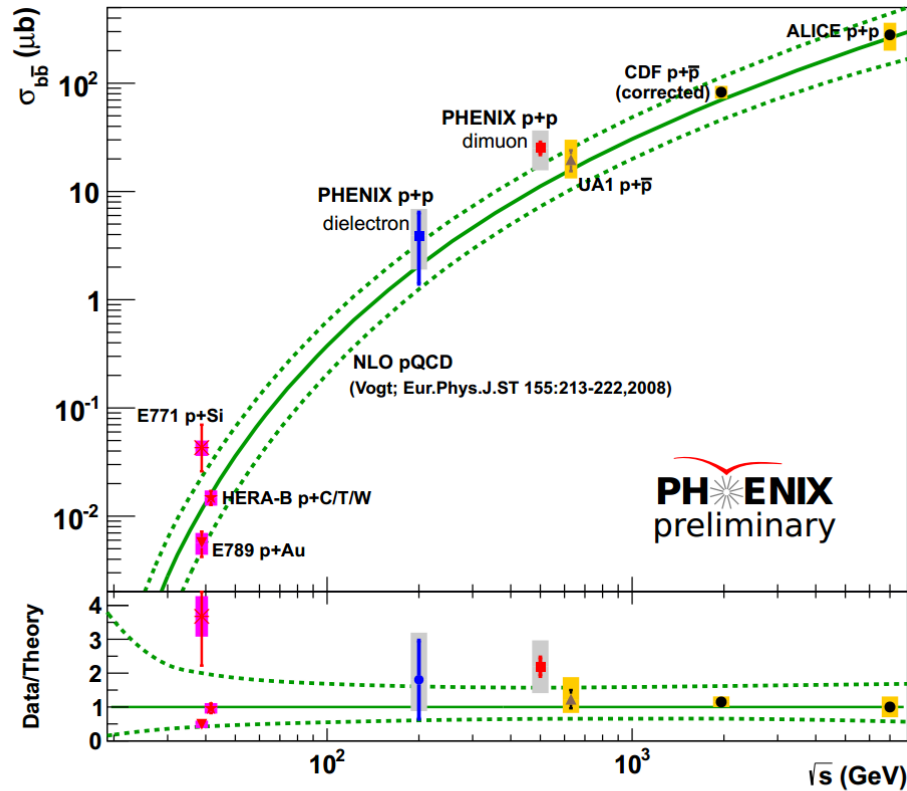


Figure 6.17: Comparison of $\sigma_{b\bar{b}}$ at different center of mass energies with NLO pQCD theory. The data point labeled “dimuon” is from this analysis. The bottom panel shows the ratio of data to NLO theory.

